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Session 1 - Systems Engineering and Intelligent Systems

Session 2 - Advances in Control Theory and Control Engineering

Session 3 - Optimisation and Management of Complex Systems and Networked Systems

Session 4 - Intelligent Vehicles and Mobile Systems

Session 5 - Robotics and Motion Systems

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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M. J. Kühn / F. Richter / H. Salzwedel

Process simulation for significant efficiency gains in clinical departments – a practical example of a cancer clinic

1 .Introduction

Cost for clinical treatments has been continuously increasing during the last several years. With 10.8% of GNP in 2003 it became the highest in Europe [1]. In order to overcome this problem, in 2004 reimbursements of hospital services based on disease patterns were introduced by the German government [2]. Under these new reimbursement rules hospitals are no longer reimbursed according to the number of days an inpatient is cared for, but on the basis of Diagnosis Related Groups (DRGs). This leads to financial restriction for inefficient hospitals that can only be compensated by better processes and cost reductions. Income and profit of hospitals may rise if treatment cost is reduced and the number of patients is increased. Treatment cost is strongly related to treatment time and number of hospital resources used during this time.

This article describes how treatment cost can be significantly reduced by model based process optimization. Standardized processes models [3] are used for the analysis. This showcase is derived from a highly successful project at a cancer clinic of a German university hospital [4].

2. Selection of simulation software

Processes in hospitals are dynamic over time. Therefore dynamic models are necessary to model these interacting and complex processes. To simulate those dynamic models, appropriate simulation software is required.

Some simulation software (e.g. CHESS [5], MedModel [6]) has been explicitly developed for the usage in hospitals [7]. An in-depth analysis of those simulation software turned out, that those systems can only be used for limited range of use. For simulating hospital processes, event-based simulation systems are required. Highly efficient and robust simulators have been developed to simulate complex communication networks and electronic systems and therefore perform much better than those developed for limited use for some aspects in hospitals. Additionally network simulators support distributed simulation, which may be required for real time hospital process optimization in hospital IT systems.
The chosen simulation system that was able to cover almost all requirements for optimizing hospital processes was MLDesigner [8]. MLDesigner belongs to class 5 simulation systems, which enables all users to rapidly develop a simulation model even without in-depth skills in programming [9].

3. Development and Validation of the simulation model

The methodology used for modeling and simulation in this study follows the steps described by Košturiak/Gregor [10]. The respective clinic covers medical examination and ambulant, chemotherapeutical treatment of cancer patients. Patients are differentiated by those, who gets only a medical examination without a therapy, and those who get examination as well as therapy (=therapy patients). The cancer clinic has an admission, one room for taking blood samples from patients, 3 examination rooms as well as a room for therapies with 24 chairs for patients. The staff includes 5 nurses and 4 medical doctors.

Patients are appointed in the timeframe between 7:30 a.m. and 8:30 a.m. for the current day. Appointments with patients get registered in the used standard software system SAP IS-H MED.

On the day of appointment a blood sample is taken from every patient right after admission. At this point, therapy patients get a venous access for further therapy. When blood analysis results are back from the laboratory, patients go to one of the physicians for medical examination, except patients who have to pass some more preliminary examinations, e.g. computer tomography. All medical findings/results as well as conducted analysis get documented and discarded in the patient documentation.

For therapy patients, the doctor decides, if the patient is able to get a chemotherapeutical therapy or not. In case of a “no go” decision, the patients get a new appointment for another day and are dismissed. If patients are in very bad condition, they will be taken inpatient. In all other cases, the therapy will be administered. Therefore the doctor calls the pharmacy for medication, which has been ordered the day before. Hereupon the pharmacy delivers the medication to the clinic’s facility. To prepare the patients, nursing staff administers the pre-medication. Upon the arrival of medication in the cancer clinic, for each patient a tray with the current medication and the therapy plan gets prepared. The doctor double-checks the tray. Afterwards, nursing stuff administers the medication to the respective patient. Depending on the pharmaceutical form and type of medication (e.g. bolus, infusion, cytostatic drug or antibodies) the necessary time for administration is variable. At the end of treatment, every patient gets a discharge note from the medical doctor. If there are no intricacies, the last patient leaves the cancer clinic around 5 p.m. The detailed process was acquired on inductive way [11] and translated into a flow chart [12].

Modeling and simulation of the process with actual data resulted in the following observations: Based on the current process steps the chemotherapeutical therapy never starts before 10:00 o’clock. Till then the 24 chairs for administration of therapy are not used for any therapy purpose, although the first therapy patients arrive at the cancer clinic at 7:30 a.m.. Furthermore we determine that the mean waiting time is very high compared to other comparable clinical facilities. Hence there were a lot of complaints from patients. Waiting time is inefficient time and therefore it must be of interest for the cancer clinic to reduce it. In addition, because of intricacies during therapy or due to patients coming late, the regular closing time often is exceeded. This leads to inefficiency in resource allocation and additional cost.

The evaluation of existing data showed that within a period of three months [13] the clinic in average serves 34 patients a day. 69 percent of the patients got no therapy and 31 percent are therapy patients.

For further analysis, additional data were collected, modeled and validated through simulation. A structured template to capture data was developed. Data were collected over a period of 55 working days. Afterwards, plausibility and completeness were checked. Based on those data, waiting times between all process steps were computed. Results for waiting time of therapy patients delivered values between 55 minutes and 5:05 hours. The average was 2:45 hours per patient. Patients stayed between 2:10 hours and 9:55 hours at the clinic. The average was 6:08 hours per patient. The ratio of waiting time to patient time was 45 percent.

System modeling has been done with MLDesigner by using the standardized building blocks, developed by Richter to speed up the modeling process [3].

The simulation model is a discrete, event based model. MLDesigner labels this type of system as “DE”. Figure 1 shows the top level of hierarchy (level 1) for this model and its interfaces to the environment. All further system elements are realized as modules (subsystem) or primitives (elements).

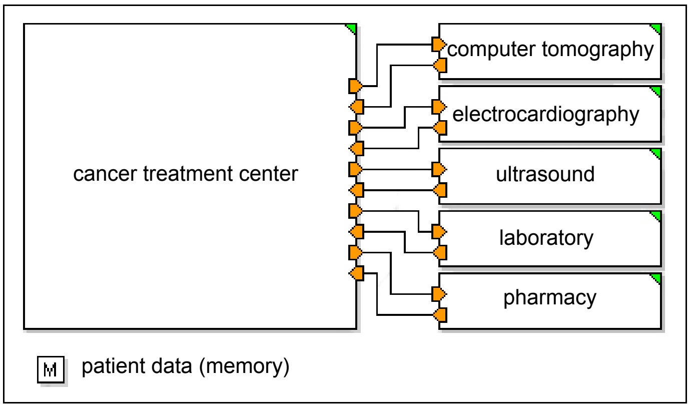


Fig. 1: Simulation model on level 1 – cancer clinic with related medical departments [14]

Relating to the master model designed by Richter [3], the processes of the clinic were organized and implemented with four main areas: admission, examination, therapy and discharge. Figure 2 shows the cancer clinic with the mentioned main areas.

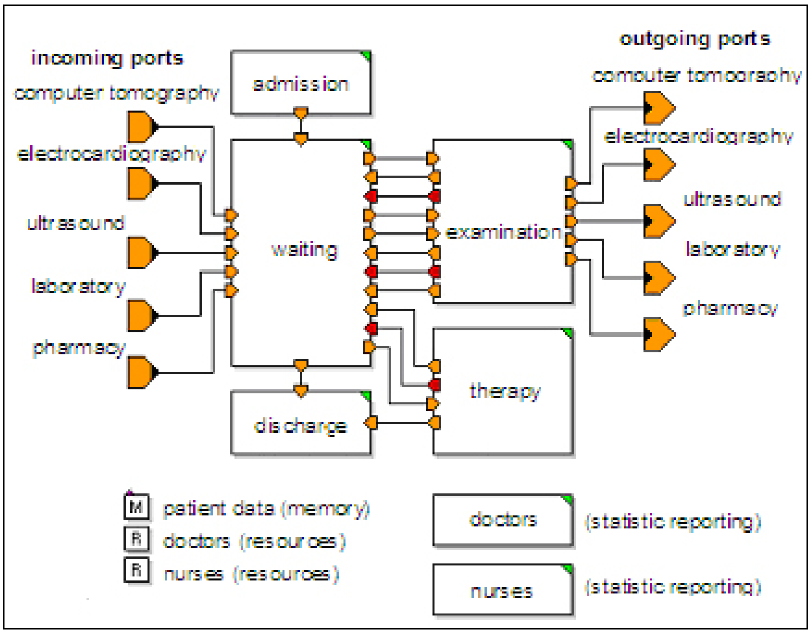


Fig. 2: Simulation model on level 2 – cancer clinic with main areas/units [14]

In the end output functions were implemented in the model to capture simulated data. MLDesigner offers a wide range of prepared functions, which also can be customized individually, e.g. statistics for the usage of resources during the simulation run.

Starting from a comprehensive catalogue of methods for validation and verification of computer models [15], selected methods were chosen to check the developed model. The deviation between model results and real data was less than 4% in average of waiting time all over, which is a good modeling result.

For validation and specially verification purposes, MLDesigner has some very useful functions. In addition to textual information about occurred failures the MLDesigner has a modeling check. Further more the simulation run can be checked with breakpoints and probes while it is running. MLDesigner permit visualization of simulation run in a standardized or user customized way.

4. Optimization of the simulation model

Analyzing simulation results, the model of existing process shows a high potential for reduction of patient time and expected treatment time. Further areas for improvements are integration with related departments like ultrasound, computer tomography or the laboratory. A third idea to optimize the cancer clinic is to check the sequence of process steps [4].

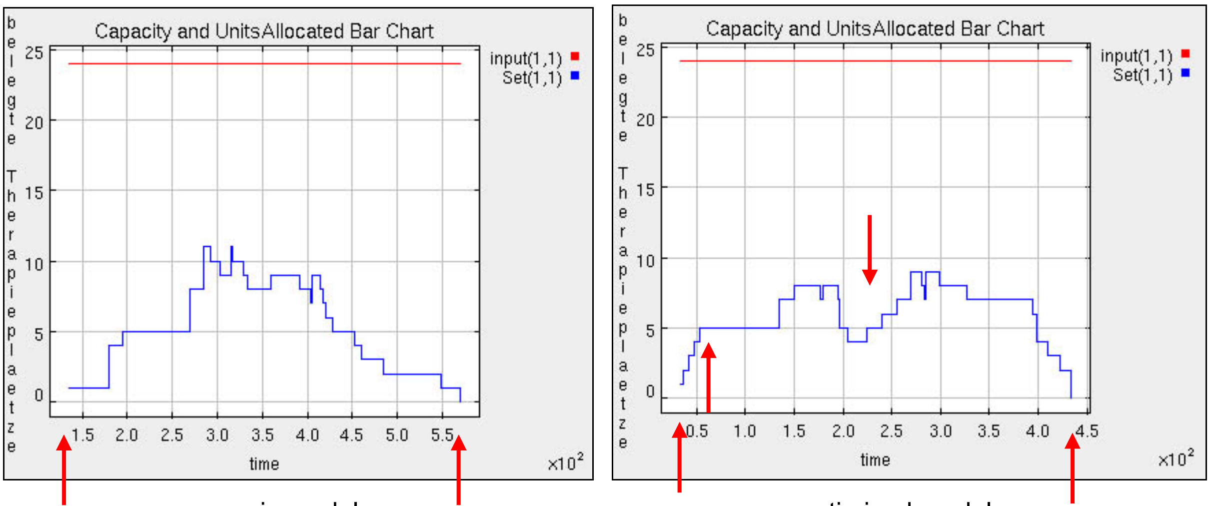
Optimization step 1: Elimination of a redundant process step:
In the past, patients who needed to get a computer tomography became a venous access (canula/needle) in the treatment center (for taking a blood sample) as well as in the radiology department (for application of radiopaque material). In the optimized simulation model, this group of patients gets only one venous access directly in the radiology department. This access will then also be used in the cancer center for taking blood samples. This saves time and increases the quality of treatment by only puncturing those patients one time instead of two times in a row.
In average 15 percent of the patients get a computer tomography. These are 5.10 patients a day based on 34 patients a day in average. The average time to apply a venous access was measured with 10 minutes. Average savings are 51 minutes a day.

Optimization step 2: Optimization of the planning sequence of scheduled patients
In the optimized model, patients were structured as groups according to their need for resources in the clinic. For example patients who will receive chemotherapy will be scheduled as the first group of patients. Patients who will only be examined by a doctor and will not get chemotherapy are scheduled as a second group.
The average reduction of waiting time in the optimized model compared to the as-is process model (after implementation of step 1 and 2) is 34 percent. This corresponds to 54 minutes in average per patient and day.

Optimization step 3: For selected patients, blood samples will be taken the day before their treatment with chemotherapy
For selected patients, blood samples will be taken the day before treatment. This enables the cancer center to receive results from the laboratory and order the chemotherapy from the hospital pharmacy the day before treatment. Those patients can then receive their chemotherapy right after admission to the cancer center.
The average reduction of waiting time in the optimized model compared to the as-is model (after implementation of step 1, 2 and 3) is 44 percent or 69 minutes in average

for each patient.

As result all key figures of the optimized model have resulted in significant improvements. Figure 3 shows the improvements on example of deployment of therapy chairs. Beginning and end of examination as well as beginning and end of therapies were significant earlier as in the existing process model. The distribution of patients over the day is more equal in optimized model compared to as-is model.



as-is model

optimized model

Fig. 3: Resource deployment of therapy chairs [14]

In average, the total waiting time of patient decreased 69 minutes. This equals an improvement of 44% for the optimized model compared to waiting time of as-is model with 158 minutes. Adjusted at calculated model deviation of 4% the total waiting time improves 66 minutes or 42% in result. The main reason for high cumulative waiting time in the existing clinical process was the result of unstructured random patient scheduling.

5. Conclusion

As the result, all project goals could be developed and demonstrated through the simulation model. All process changes have been implemented at the cancer clinic and delivered similar results. Resource utilization increased and opening hours could be reduced. The same number of patients can now be treated with reduced opening hours, less cost, and less effort.

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